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ESTIMATING LIVE WEIGHT OF PHILIPPINE DAIRY BUFFALOES (*Bubalus bubalis*) USING DIGITAL IMAGE ANALYSIS

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ABSTRACT

Two regression models were developed to predict the live weight of dairy buffaloes (*Bubalus bubalis*) using digital image analysis. The first model relates the live weight with measurements of body length (BL), wither height (WH), fore girth depth (FD), hip height (HH), rear depth (RD), and diagonal length (DL). The second model relates the live weight to the number of pixels present in a segmented digital image of the animal. Body measurements and pixel counting were done by processing the digital images of the animal using ImageJ. Stepwise regression analysis revealed that BL, WH, and FD significantly affected the changes in live weight of dairy buffaloes at $P < 0.05$. Further analysis showed that dimension-based regression model (R^2= 0.94 and RMSE = 22.12) performed better than pixel-based model (R^2= 0.87 and RMSE = 23.22) in estimating live weight of dairy buffaloes.

Keywords: body measurements, dairy buffaloes, digital image analysis, live weight, pixel count

INTRODUCTION

Live weight determination plays an important role in various livestock operations such as selection, breeding, feeding and health care (Yakubu, 2010). Replacement animals need to have good body size and weight for efficient breeding and milk production. A decrease in live weight of animals may also indicate health problems, inappropriate environmental conditions or feeding faults (Tasdemir *et al*., 2011). Animal live weight is also crucial in the design of environmental control for animal housing and waste management system for livestock farms (Esmay, 1978; Esmay and Dixon, 1986).

The traditional on-farm method of measuring live weight of animals involves forcing the animals to stand on top of a weighing scale. The animals are difficult to guide from the pen to the weighing system. Farm workers usually have a hard time separating one dairy buffalo from the herd because the alley along the weighing system can only accommodate one dairy buffalo at a time. It would take more than an hour to weigh a total of 20 dairy buffaloes. Hence, manual method of live weight measurement is time-consuming, laborious, and stressful to animals.

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Alternatively, animal live weight can be successfully estimated using body measurements as reported in previous researches (Abdelhadi and Babiker, 2009; Zaragosa, 2009; Cam *et al*., 2010, Tasdemir *et al*., 2011, Perez *et al*., 2016). Recent developments in computer and digital technology make it possible for image analysis to be conveniently used to estimate animal live weight with a higher degree of accuracy. Using an opti-informatic system consisting of a digital camera, laser telemeter, image analysis software, and a computer, Negretti *et al*. (2007) performed visual image analysis (VIA)-based measurements of morphological traits to predict the live weight of rabbits. A linear regression equation relating the lateral body surface of adult rabbits to its live weight generated an R^2 of 0.87 ($P<0.01$) and prediction error of 3% and 5% at 65% and 35% of the sample, respectively. Mollah *et al*. (2010) estimated the live weight of broilers based on pixel count of digital images and day age. Pixel counting was done using raster image analysis in IDRISI 32. The model developed had 0.999 degree of goodness of fit and percent error ranging from 0.04 to 16.47 %. Tasdemir *et al*. (2011) used digital image analysis to determine body measurements of Holstein cows. Digital photos of cows at various angles were taken from different angles synchronously and analyzed to estimate wither height, hip height, body length, and hip width. Live weight of dairy cows was also estimated from a linear regression model developed based on the body measurements. The authors reported a 0.9787 correlation between the estimated and manual live weight values. The present study aimed to use digital image analysis in developing linear regression models to estimate live body weight of Philippine dairy buffaloes.

MATERIALS AND METHODS

The study was conducted in the research farm of PCC at UPLB, College Laguna. There were 23 dairy buffaloes used in the study which were crossbreds of native carabao and Murrah buffalo. The age of the dairy buffaloes at the start of the data collection ranged from 12 months to 24 months old.

Live weight of the animal was recorded using an electronic weighing system consisting of a load bar weighing scale, a wooden platform, and a digital monitor display. The weight displayed in the monitor had an increment of 0.1 kg. Live weight measurements were carried out every two weeks for a period of seven months using the same animals. The model dataset includes 165 observations, of which 135 observations were used for model development while 30 observations were used for model validation. Data were collected early in the morning and right before feeding to minimize the effect of stomach fullness on live weight measurement. Water was available at all times.

Lateral images of dairy buffaloes were taken simultaneously with actual live weight measurement using a commercial digital camera (Sony Cybershot DSC – W320). The distance of the digital camera from the animal is maintained at 2 meters. As can be seen in Figure 1, the captured digital image included a dairy buffalo standing on top of a wooden platform with a weighing scale underneath. A white cloth was used as a background for simplifying the image process by isolating the dairy buffalo from the background. The leveling rod was used for calibrating body measurements using image analysis.

As shown in Figure 2, measurements of body length (BL), wither height (WH), fore girth depth (FD), hip height (HH), rear depth (RD), and diagonal length (DL) were

Figure 1. Sample digital image of dairy buffalo.

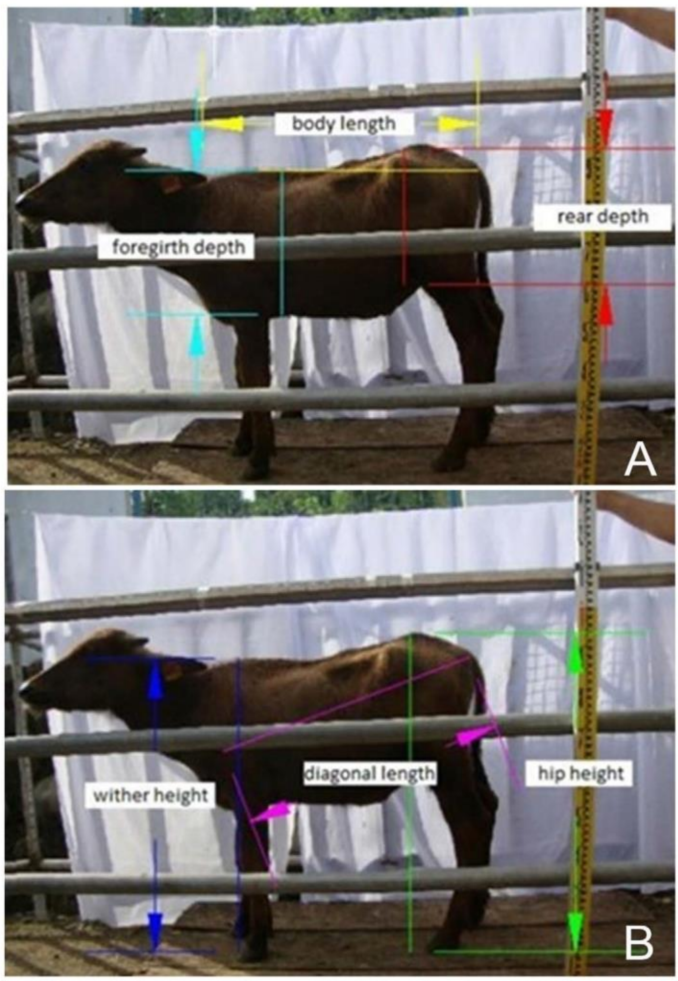

Figure 2. Linear body measurements of dairy buffalo showing A) body length (BL fore girth depth (FD), and rear depth (RD); and B) wither height (WH), diagonal length (DL), and hip height (HH).

determined from the captured digital images of dairy buffalo. A Java-based image processing software called ImageJ was used to perform body measurement calculations.

The lateral surface area of the dairy buffalo was determined using the same image processing software. The digital image was converted into a binary image and further filtering was carried out to isolate the animal image from the background. The resulting image was then analyzed to calculate the lateral surface area as represented by the number of pixels. Figure 3 shows the image process flow diagram for calculating the number of pixels of the animal image.

A linear regression model based on the body measurements of BL, WH, FD, HH, RD, and DL was developed to estimate the live weight of dairy buffalo using Microsoft Office Excel regression tool. The general form of the equation is described as:

$$\mathbf{y = \alpha + b_1X_1 + b_2X_2 + \ldots\ldots + b_kX_k}$$

where **y** is the dependent variable,
α is the intercept,
$\mathbf{b_i}$ **(i= 1 to k)** is the partial regression coefficient associated with the independent variable $\mathbf{X_i}$.

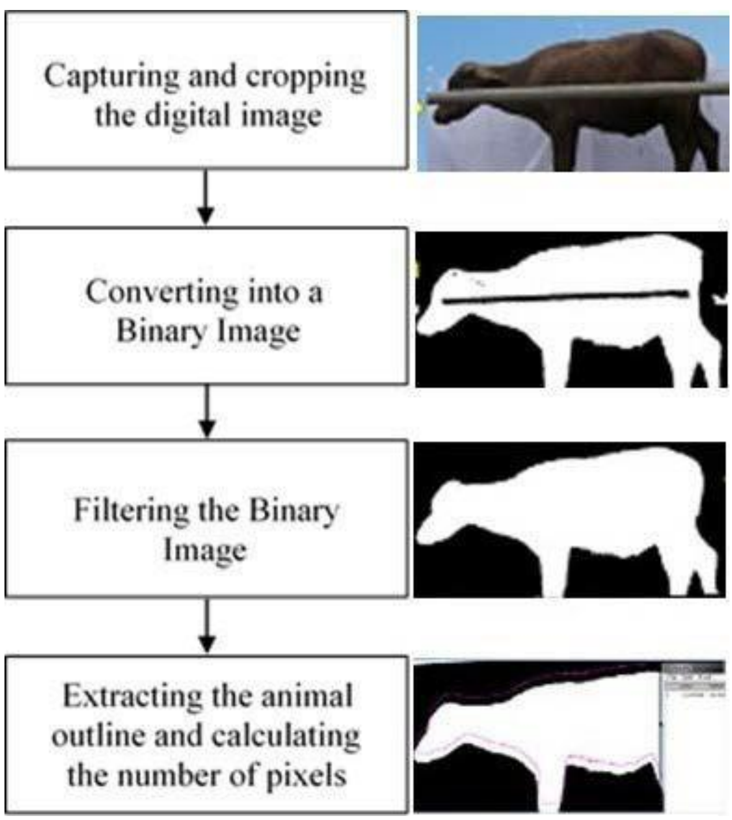

Figure 3. Image process flow diagram for calculating lateral body surface area using ImageJ.

Stepwise regression technique was performed to include in the linear regression equation only those body measurements that contribute significantly ($P<0.05$) to the variation in the live weight of dairy buffalo. Another linear regression model was developed to estimate the animal live weight based on the total number of pixels of the digital image of the lateral body surface area.

Using the established regression models, live weights of dairy buffaloes were predicted and compared with measured live weights using data sets not included in the model development. Both models were assessed based on the coefficient of determination (R^2) and root mean square error (RMSE). The RMSE was calculated using the equation:

$$\mathbf{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(\mathbf{LW_{pi}} - \mathbf{LW_{ai}})^2}{\mathbf{n}}}$$

where **RMSE** is the root mean square error,
$\mathbf{LW_{pi}}$ is the predicted animal live weight (kg),
$\mathbf{LW_{ai}}$ is the actual animal live weight (kg),
n is the sample size

RESULTS AND DISCUSSION

As shown in Table 1, the live weight of dairy buffaloes used in the beginning of the study ranged from 33.40 kg to 287 kg with a standard deviation of 69.78 kg.

Least squares linear regression was used to establish the linear relationship of each body dimension among each other. Table 2 shows significantly high linear relationship

Table 1. Descriptive statistics of live weight and body measurements of dairy buffaloes.

	LW (kg)	BL (cm)	WH (cm)	FD (cm)	HH (cm)	RD (cm)	DL (cm)
Minimum	33.40	502.40	572.40	259.20	592.60	282.80	434.70
Maximum	287.00	1,077.80	1,014.10	552.90	1,079.80	578.10	1,091.10
Mean	147.49	812.48	839.34	422.21	895.14	434.30	811.97
SD	69.78	156.41	113.10	75.19	119.27	73.41	157.65

Table 2. Pearson's correlation table for body dimension parameters.

	BL	WH	FD	HH	RD	DL
WH	0.963					
FD	0.980	0.974				
HH	0.974	0.980	0.972			
RD	0.950	0.933	0.956	0.961		
DL	0.988	0.954	0.978	0.971	0.954	
WT	0.958	0.894	0.940	0.913	0.914	0.949

among each parameter with BL and DL had the highest (0.988) while WH and RD had the lowest (0.933). In terms of their correlation to live weight, BL had the highest (0.958) while WH had the lowest (0.894).

Stepwise linear regression was done to eliminate insignificant parameters (P>0.05) one at a time. The process took three steps as shown in Table 3, leaving only BL, WH and FD in the body dimension model:

$$\mathbf{LW} = 0.529\mathbf{BL} - 0.393\mathbf{WH} + 0.485\mathbf{FD} - 136.373$$

where **LW** is the animal live weight (kg),
BL is the body length (cm),
WH is the wither height (cm), and
FD is the fore girth depth (cm)

From the same set of dairy buffaloes, binary images were obtained and the number of pixels of each animal image were recorded and summarized in Table 4.
Simple linear regression was used to establish the relationship between the live weight and the number of pixels of lateral body surface area of the animal as shown in Figure 4. The model yielded a high coefficient of multiple determination (R^2=0.878):

$$\mathbf{LW= 1.543 \times 10^{-4}(N) - 72.055}$$

where **LW** is the live weight of animal (kg) and
N is the no. of pixels of lateral body surface area.

The models derived from the previous methods were validated using 30 independent data sets. From Table 5, the estimated weight using dimension-based model resulted to higher R^2 (0.94) and a lower value of RMSE (22.12) which means body dimension-based model can yield more consistent results in terms of estimation of animal live weight. In Figure 5, the plot of the estimated live weight using dimension-based model deviated slightly from perfect linearity. From the graph, live weights below 200 kg tend to be overestimated with this model. Many points along this range appear above the line of perfect linearity. This also implies underestimation of the live weight measurements if above 200kg. Applying additional constants could align the results to more accurate measurements.

On the other hand, estimated live weights using pixel-based model had lower R^2 (0.87) and a higher value of RMSE (23.22) than that of dimension-based model. This implies more inconsistent estimates which could arise from the processing of the binary images. In Figure 6, it can be observed that many points in the middle range of the graph appear above the line of perfect linearity, while the points at the ends, both higher and lower weights, tend to cluster along or below this line. This could indicate a slight curvilinear response in the number of pixels to the animal live weight. Thus, this relationship should be explored.

Further modifications of the models may be applied to improve the accuracy of both methods. In addition, other camera angles may also be considered to account for cross-sectional measurements.

In other past studies, high correlation between animal live weight and body dimensions was also observed. Tariq *et al.* (2013) generated models for estimating Nili-Ravi buffalo weights using body length, heart girth and shoulder height. An R^2 = 0.94 was

Table 3. Results of stepwise linear regression.

	Step 0		Step 1		Step 2		Step 3	
Parameters	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Constant	-136.373	0	-136.373	0	-136.373	0	-136.373	0
BL	0.538	0	0.555	0	0.557	0	0.529	0
WH	-0.303	0.002	-0.311	0.001	-0.339	0	-0.393	0
FD	0.401	0.017	0.417	0.009	0.480	0.001	0.485	0.001
HH	-0.137	0.171	-0.129	0.180	-0.086	0.331		
RD	0.102	0.282	0.105	0.262				
DL	0.025	0.760						

Table 4. Descriptive statistics of live weight and number of pixels of dairy buffaloes.

	Weight, (kg)	Number of Pixels
Minimum	33.40	556,816.00
Maximum	287.00	2,104,643.00
Mean	147.49	1,350,215.13
SD	69.78	411,301.09

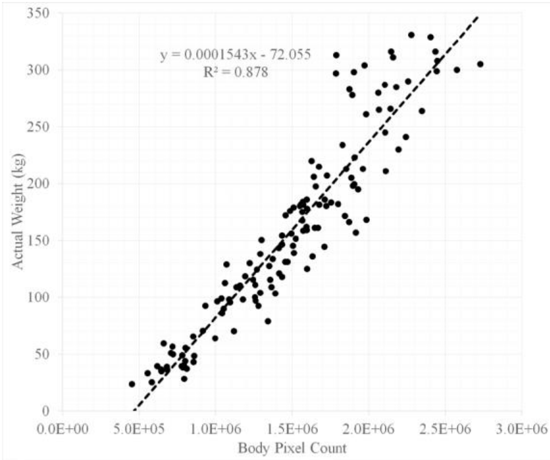

Figure 4. Relationship between body pixel count and the animal live weight.

Table 5. Summary of the statistical parameters for validating dimension-based and pixel-based live weight models.

	Measured Live Weight (kg)	**Predicted Live Weight – Body Dimension (kg)**	**Predicted Live Weight – Body Pixels (kg)**
Mean	152.92	165.76	156.51
Variance	4335.17	3036.90	3823.25
R^2		0.94	0.87
RMSE		22.12	23.22

obtained for buffaloes of age 1 to 3 years, $R^2 = 0.80$ for 3 to 8 years, and $R^2 = 0.71$ for more than 8 years. Similarly, Buranakarl *et al*. (2012) included other body dimensions such as iliac width, ischial tuberosity width, length of shoulder to iliac wing, length of iliac wing to ischial tuberosity, and length of shoulder to ischial tuberosity. Their models yielded $R^2 = 0.82$ for males and $R^2 = 0.89$ for females. However, Heinrich *et al*. (1992) showed that addition of multiple body traits as independent variables in estimating body weight of Holstein heifers had little effect on already high multiple correlations found with a single independent variable.

Pixel-based estimation of live weight were also tested for other animals such as rabbits (Negretti *et al*., 2007), poultry (Mollah *et al*., 2010), and pig (Yang and Teng, 2008). This method yielded favorable results however, additional parameters maybe included in the model such as age of the animal or even body dimensions to further improve its accuracy.

In conclusion, linear regression models were developed and validated for estimating live weight of dairy buffaloes using digital image analysis. Six different body measurements were selected in the establishment of dimension-based model. However, stepwise regression analysis revealed that body length, wither height and fore girth depth are the only linear body measurements significantly affecting live weight of dairy buffaloes. On the other hand, a pixel-based model was developed to relate the live weight of dairy buffaloes to the number of pixels generated from the processed binary digital images of the lateral body surface area

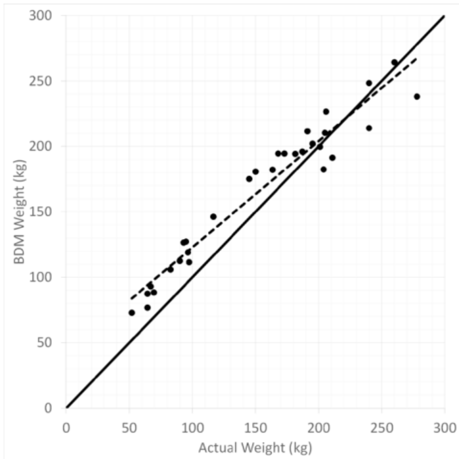

Figure 5. Plot of estimated live weight using dimension-based model (dashed line) to perfect linearity (solid line).

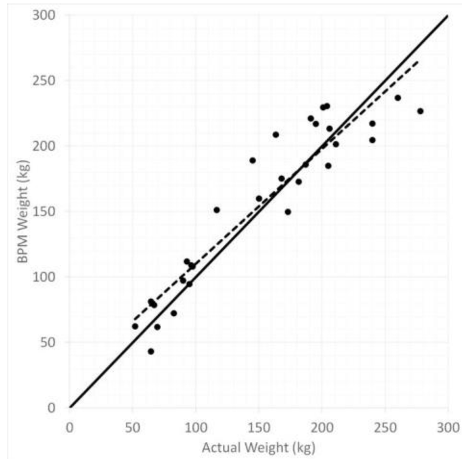

Figure 6. Plot of estimated live weight using pixel-based (dashed line) to perfect linearity (solid line).

of the animal. The dimension-based model and pixel-based model showed coefficient of determination of 0.94 and 0.87, and root mean square error of 22.12 and 23.22, respectively. The results suggest that dimension-based model performed better than pixel-based model.

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